"To obtain a mixture of acetylene and turpentine oil in DI CI engine"

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By

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ABSTRACT

With modernization and increase in the number of automobiles world wide, the consumption of diesel and gasoline has enormously increased. As petroleum is non renewable source of energy and the petroleum reserves are scarce nowadays, there is a need to search for alternative fuels for automobiles. Work has been done in using a lot of biofuels, the fuels obtained from plant to be used in IC engines which have an even added advantage of lower emissions compared to that of diesel and gasoline. Turpentine oil has been used in direct injection CI engine as an alternate fuel has similar properties as that of diesel. Acetylene is also a very good alternate fuel. In the present work, a mixture of acetylene and turpentine oil is obtained (as both of them are good alternative fuels) to be used in CI engine. The mixture is optimized such that it gives a thermal efficiency of 30% in a diesel engine at different loaded conditions. Thereafter, the properties of the mixture obtained are studied and represented in a graphical form.

CONTENTS

Chapter 1

Introduction

INTRODUCTION

Depleting petroleum reserves and increasing cost of the petroleum products necessitates an intensive search for alternative fuels which can wholly or partially replace petrofuels. Biofuels are tested from times and they prove to be very good substitutes for the existing petrofuels. They require a little engine modification to be used in IC engines. Nowadays gases like LPG (liquefied petroleum gas), LNG (liquefied natural gas), acetylene, etc. are being used as substitute of diesel and gasoline in IC engines. These are inducted into the engine along with the air coming into the engine.

Generally, biofuels are obtained from the living plant sources. These oils may be obtained from resin and plant seeds. They are renewable and have low sulphur content. There widespread use as an IC engine fuel is restrained because they are more costly than fossil fuels. Vegetable oil is in use as a diesel engine fuel before all other alternative fuels were tried. But the problems associated with vegetable oil are the high viscosity and low volatility. These properties affect the fuel injection system very badly. Turpentine was used in early engines without any modification. The abundant availability of petrofuels had stopped the usage of turpentine in I.C. engines. But the increasing cost of petrofuel prevailing today reopens the utility of turpentine in I.C. engine. [1]

Turpentine oil can be used in diesel engine as turpentine-oil and diesel blend or duel fuel mode [1]. Using turpentine oil in duel fuel mode in diesel engine the CO and UHBC emissions are slightly higher than diesel base line and NOx emission is found to be almost same [1].

The gaseous fuels are used in duel fuel mode in IC engines. Since gaseous fuels have high auto-ignition temperature, they can't be used directly in CI engines easily. Hence they are normally used in DF mode. The dual fuel engine us the modified diesel engine in which usually a gaseous fuel called the primary fuel is inducted with air. The gaseous fuel-air mixture is then compressed but doesn't auto-ignite as it has a high self-ignition temperature. A small amount of diesel usually called the pilot, is injected as in a normal diesel engine, near the end of the compression stroke. The pilot diesel fuel auto ignites and acts as a spark or source for the ignition of the primary fuel-air mixture. The combustion of gaseous fuel occurs due to the flame that propagates through[2]. Thus the dual fuel mode combines the feature of CI and SI engine. Fuel injection is the part of CI engine and the compression of charge and propagation of flame is the part of SI engine.

With the use of acetylene, the HC,CO,CO_2 and smoke emissions were less as compared to diesel baseline engine. But the NOx emissions are increased significantly [2].

In the present work we are designing an apparatus to obtain a mixture of both turpentine oil and gasoline which can be inducted into the direct injection CI engine. The mixture is optimized such that it gives thermal efficiency of 30% at different loaded conditions with taking three sets of acetylene flows and getting the corresponding flow rates for the turpentine oil. After that, the properties of the mixture obtained are represented o graphs.

Chapter 2

Literature review

Important qualities of engine fuels

The fuel must have certain physical, chemical and combustion properties in general which are enumerated below:-

1) High energy density.
2) Good combustion qualities.
3) High thermal stability.
4) Low deposit forming tendencies.
5) Compatibility with the engine hardware.
6) Good fire safety.
7) Low toxicity.
8) Low pollution.
9) Easy transferability and onboard vehicle storage.

These properties are elaborated by dividing the fuels for SI and CI engines. Fuels used in ic engines should possess certain basic qualities which are important for smooth running of engines. In this section the important qualities of fuels for both SI and CI engines are shown.

SI Engine Fuels

Gasoline which is mostly used in the present day SI engines is usually a blend of several low boiling paraffins, napthalenes and aromatics in varying proportions. Some of the important qualities of gasoline are discussed below.

1) Volatility:- Volatility is one of the main characterstic properties of gasoline which determines its suitability for use in an SI engine. Since gasoline is a mixture of different hydrocarbons, volatility depends on the fractional compositon of the fuel. The usual property of measuring the fuel volatility is the distillation of the fuel in special device at atm pr. And the presence of its own vapour. The fraction that boils off at a definite temp. is measured. The characterstic ponts are the temperature at which 10, 40, 50 and 90% of the volume evaporates as well as temperature at which boiling of the fuel terminates. The method of measuring volatility is standardized by American Society of Testing Materials(ASTM) and

the graphical representation of the tests is generally termed as the ASTM distillation curve. The more important aspects of volatility related to engine fuels are discussed in the following bits.

2) Starting and warming up:- A certain part of gasoline should vapourize at room temperature for easy starting of the engine. Hence the portion of the distillation curve between 0 and 10% boiled off have relatively low boiling temperatures. As the engine warms up, the temperature will gradually increase to the operating temperature. Low distillation temperatures are desireable throughout the range of the distillation curve for best warm-up.

3) Operating range performance:- In order to obtain good vapourisation of the gasoline, low distillation temperatures are preferable in the engine operating range. Better vapourisation tends to produce both more uniform distribution of fuel to the cylinders as well as better acceleration characterstics by reducing the quantity of liquid droplets in the intake manifold.

4) Crankcase dilution:- Liquid fuel in the cylinder causes loss of lubricating oil(by washing away oil from the cylinder walls) which deteriorates the quality of lubrication and tends to cause damage to the engine through increased friction. The liquid gasoline may also dilute the lubricating oil and weaken the oil film between rubbing surfaces. To prevent this situation, the upper portion of the distillation curve should exhibit sufficiently low distillation temperatures to ensure that all gasoline in the cylinder is vapourized by the time the combustion starts.

5) Vapour lock characterstics:- High rate of vapourisation of fuel can upset the carburetor metering or even stop the fuel flow to the engine by setting up a vapour lock in the fuel passages. This characterstic demands the presence of relatively high boiling temperature through out the distillation range.

6) Antiknock quality:- Abnormal burning or detonation in an SI engine combustion chamber causes a very high rate of energy release, excessive temperature and pressure inside the cylinder adversely effects its thermal efficiency. Therefore, the characterstic of fuel should be such that it reduces the tendency to detonation and this property is called its antiknock property. The antiknock property of a fuel depends on the self-ignition characterstics of its mixture and vary largely with the chemical composition and molecular structure of fuel. In general, the best SI engine fuel will be that having the highest antiknock property, since this permits the use of higher compression ratios and thus the engine thermal efficiency and the power output can be greatly increased.

7) Gum deposits:- Reactive hydrocarbons and the impurities in the fuel have a tendency to oxidize and form liquid and solid gummy substances. Unsaturated hydrocarbons are more prone to form gum deposits. Gum deposits may lead to clogging of carburetor jets and enlarging of the valve stems, cylinders and pistons.

8) Sulphur content:- Hydrocarbon fuels may contain free sulphur, hydrogen sulphide and other sulphur compounds which are objectionable for several reasons. The sulphur is the corrosive element of the fuel that can corrode fuel lines, carburetors and injection pumps and it will unite with oxygen to form sulphur dioxide that, in presence of water at low temperatures, may form sulphurous acid. Since sulphur has a low ignition temperature, the presence of sulphur can reduce the self-ignition temperature, then promoting knock in the SI engine.

CI Engine Fuels

1) Knock characteristics:- Knock in the CI engine occurs because of an ignition lag in the combustion of the fuel between the time of injection and the time of actual burning. As the ignition lag increases, the amount of fuel accumulated in the combustion chamber increases and when combustion actually takes place, abnormal amount of energy is suddenly released causes an excessive rate of pressure rise which results in an audible knock. Hence, a good CI engine fuel should have a short ignition lag and will ignite more readily. Furthermore, ignition lag affects the starting, warm up, and leads to the production of exhaust smoke in CI engine. The present day measure in the cetane rating, the best fuel in general, will have a cetane rating sufficiently high to avoid objectionable knock.

2) Volatility:- The fuel should be sufficiently volatile in the operating range of temperature to produce good mixing and combustion.

3) Starting Characteristics:- The fuel should help in starting the engine easily. This requirement demands high enough volatility to form a combustible mixture readily and a high cetane rating in order that the self-ignition temperature is low.

4) Smoking and odor:- The fuel should not promote either smoke or odour in the engine exhaust. Generally, good volatility is the first prerequisite to ensure good mixing and therefore complete combustion.

5) Viscosity:- CI engine fuel should be able to flow through the fuel system and the strainers under the lowest operating temperatures to which the engine is subjected to.

6) Corrosion and Wear:- The fuel should not cause corrosion and wear of the engine components before or after combustion. These requirements are directly related to the presence of sulphur, ash and residue in the fuel.

7) Handling Ease:- The fuel should be a liquid that will readily flow under all conditions that are encountered in actual case. This requirement is measured by the pour point and the viscosity of the fuel. The fuel should also have a high flash point and a high fire point

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Rating of fuels:-

Rating of fuels is normally done for their antiknock qualities. The rating of fuels is done by defining two parameters cetane number and octane number for diesel and gasoline respectively. Here the detailed description of the rating is given.

Rating of CI engine fuels:-

The knock resistance depends on chemical properties as well as on the operating and design conditions of the engine. So the knock rating of a diesel fuel is found by comparing the fuel at a specific condition with primary reference fuels. The reference fuels are normal cetane $C_{16}H_{34}$, which has been assigned a cetane number of 100 and alpha methyl naphthalene, $C_{11}H_{10}$, with a cetane number of 0.

Def. Cetane number of a fuel is defined as the percentage by volume of normal cetane in a mixture of normal cetane and alpha methyl naphthalene which has the same ignition characteristics (ignition delay) as the test fuel when combustion is carried out in a standard engine under specified operating conditions.

The knock should be directly related to the ignition delay as it is the major factor in controlling of the autoignition in the CI engine. Knock resistance property of a diesel oil can be improved by adding small quantities of compounds like amyl nitrate, ethyl nitrate or ether.

Rating of SI engine fuels:-

The knock resistance is the most important characteristic of the fuel for SI engine. The fuels differ widely in their ability to resist knock depending on their chemical composition. In addition to the chemical properties of the hydrocarbons in the fuel other operating parameters such as fuel-air ratio, ignition timing, dilution, engine speed, shape of combustion chamber, ambient conditions, compression ratio etc. affect the tendency to knock in the engine cylinder. Therefore, in order to determine the knock resistance characteristic of the fuel, the engine and its operating variables must be fixed at standard values.

Here also there are two reference fuels viz. iso-octane (C_8H_{18}) chemically being a very god antiknock fuel, has been assigned an octane number of 100 and normal heptane (C_7H_{16}), it has very poor antiknock qualities and is assigned an octane number of 0.

Def. The octane number of a fuel is defined as the percentage, by volume, of iso-octane in a mixture of iso-octane and normal heptanes, which exactly matches the knocking intensity of the fuel in standard engine under a set of standard operating conditions.

The octane number at the higher range of scale will produce greater antiknock effect compared to the same unit at the lower end of the scale e.g. octane number increase from 90 to 91 produces greater antiknock effect than a similar increase from 30 to 31. The addition of some chemicals like tetra ethyl lead(TEL) to iso-octane produces fuels of greater antiknock qualities.

Some additives are used to improve the combustion in the IC engines which are discussed in the next section.

Additives:-

Some compounds called additives or dopes are used to improve the combustion properties of fuels. The main combustion problems that arise when the operating conditions become severe are knocking and surface ignition. That can be tackled by a lot of ways of which one is using additives.

For an additive to be acceptable, it must satisfy some basic requirements. These are as follows:-

1) It must be affective in desired reaction that is knock resistance or surface ignition or both.
2) It should be soluble in fuel under all conditions.
3) It should be stable in storage and have no adverse effect on fuel stability.
4) It should be in the liquid phase at normal temperature, and volatile to give rapid vaporization in the manifold.
5) It must not produce harmful deposits.
6) Its water solubility must be minimum to minimize handling loses.

Alternative fuels for SI and CI engines:-

There are three types of fuels viz. solid, liquid and gaseous fuels. Mainly liquid fuels are used in ic engines. Nowadays gaseous fuels such as LPG and CNG are also in use as automobile fuels. In early periods even solid fuels like charcoal, coal and slurry were also tried.

Solid fuels:-

They are not used nowadays, but when Rudolf was designing the engine he used coal dust mixed with water. He used very fine coal particles thoroughly mixed with water and injected in the engine. As coal is abundantly available it becomes an attractive fuel, but there are problems in using it. Major problems are abrasiveness due to solid particles which leads to wear of injectors and the piston rings.

Liquid fuels:-

Liquid fuels are preferred due to their high calorific value and they can be easily stored. Moreover the problem of wear is also overcome by using liquid fuels. The most common liquid alternative is alcohol. Alcohol has both advantages and disadvantages as a fuel which is discussed below.

Advantages:-

1) It can be manufactured and even obtained from natural sources.
2) It has a high octane number even greater than 100, so a large compression ratio can be employed.
3) It has higher flame speed.
4) Overall emissions produced by alcohol are less than gasoline.
5) It provides higher pressure and more power in the expansion stroke.
6) Sulphur content is less in alcohols.

Disadvantages:-

1) The calorific value of alcohol is very less, almost half of the general fuels used in ic engines. That means the fuel quantity required to produce a certain amount of power is doubled if we use alcohol, which inturn means that a vehicle can travel only half the distance with full fuel tank as it would have travelled if gasoline was used.
2) It is more corrosive than gasoline on metal and plastic parts. So use of alcohol puts restrictions on the design of the engine. All the parts like piston rings gaskets, etc. get worn out by long term alcohol use.
3) Its combustion produces aldehydes in the exhaust which is not acceptable.
4) They have poor ignition characteristics in general.
5) Its use leads to poor starting characteristics in cold weather.
6) Air can enter the storage tank due to low vapor pressure of alcohol and can form combustible mixture.

Mainly methanol and ethanol are used as fuel in ic engines.

Gaseous fuels:-

Since physical delay is almost zero for gaseous fuels, they are suited for use in ic engines. Since the gas displaces the equal amount of air, the volumetric efficiency of the engine decreases. The major gaseous fuels are as follows:-

A) Hydrogen :-

Advantages of hydrogen:-

1) Since there is no carbon in the fuel so the emissions are devoid of CO or HC. The exhaust mainly consists of H2O, N2 and NOx.
2) It is easily available. It can be manufactured by a number of ways including electrolysis of water.
3) If incase it is leaked to environment, it doesn’t act as a pollutant.

4) It has high energy content per unit volume. So for a given tank size, a larger distance can be traversed.

Disadvantages of hydrogen as a fuel:-

1) It is difficult to refuel and the possibility of knocking is more.
2) The volumetric efficiency decreases by the use of hydrogen as a fuel.
3) The flame temperature is very high so the NOx emissions increase.
4) Its operation is costlier than gasoline.
5) It has a lot of storage problems. In liquid state, it requires a thermally insulated fuel tank. In gas phase, it will require high pressure vessel with limited capacity.

Hydrogen can be used in diesel engines in 2 ways:-

1) By using in a dual fuel mode, in which hydrogen is inducted along with air and then the mixture of air and hydrogen is compressed in the cylinder. At the end of the compression stroke diesel is injected and the combustible mixture is burned. But hydrogen should be put in certain limits as it can lead to high pressure rise.
2) By surface ignition. Hydrogen is sprayed at the end of the compression stroke directly inside the cylinder. But the self ignition temperature of hydrogen is high, so it is sprayed on the hot glow plug in the combustion chamber which leads to the burning of hydrogen. This is known as surface ignition.

Hydrogen is a very reactive fuel, so a lot of care is to be taken in handling it. A flame arrester should be used to stop any possible back flash to the storage tank from the engine cylinder.

B) Natural gas:-

Natural gas is very easily available and is present at a number of locations. It can be easily obtained by process of drilling wells. When natural gas is obtained from drilling wells, it is known as casing head gas. It is generally treated for obtaining gasoline. When gasoline is taken out from natural gas, it is known as dry gas. Natural gas mainly consists of methane (60-95%) and other hydrocarbons. It also contains various amounts of N2, CO2, He and traces of other gases. When sulphur content is low, it is called sweet or else sour. It can be stored in two ways that is as compressed natural gas (CNG) and liquefied natural gas (LNG). In CNG, pressure of 16-25 bar is maintained and in LNG 70 to 210 bar at a temperature around -160^{o}c. Now the advantages and disadvantages of the natural gas are discussed below.

Advantages of natural gas:-

1) Octane number of natural gas is very high about 110. So, it has a very high flame speed and thus provides a higher compression ratio.
2) Emissions are comparatively less. The aldehyde content in the emission is considerably less than methanol.
3) Natural gas is abundantly available in the world.

Disadvantages of natural gas as fuel:-

1) Volumetric efficiency of the engine decreases as it is a gaseous flow so the amount of air intake by the engine decreases.
2) Energy density is low which leads to low engine performance.
3) Fuel properties are inconsistent.
4) Refueling is a slow process.
5) Large pressurized fuel tank is required for its storage.

Methane is used with diesel in CI engine. Methane becomes the major component (90% of methane in the mixture). Methane is introduced in the engine cylinder with the help of pressurized pipes.

Compressed natural gas (CNG) is nowadays commonly used in big cities like Delhi, where the emissions from automobiles have crossed the limits as the emissions from burning of CNG are considerably less as compared to the emissions produced by a gasoline engine. CO emission is almost nullified by the use of CNG.

C) Liquefied petroleum gas:-

Propane and butane are mainly used as LPG. Both are obtained from the drilling well process. Sometimes they are used alone and sometimes combination of the two is used in the engine. These gases are compressed and cooled and stored under pressure in tanks in liquid form which are sealed.

Advantages of LPG as a fuel:-

1) Emissions are less when the vehicle is run with LPG. The carbon content in LPG is less than that of petrol, so the CO emissions are very less almost half of that of gasoline. And the nitrogen compounds emissions are also reduced slightly.
2) It can be uniformly supplied to all the cylinders in multi-cylinder operation.
3) LPG is miscible in air at all temperatures.
4) Propane can be used for higher compression ratios.
5) Since the fuel is in vapor form, crank case dilution is not there.
6) It has good antiknock characteristics.
7) 50% of cost is saved if LPG is used as a fuel.
8) The engine life is increased by 1.5 times.
9) Its high octane value compensates the thermal efficiency of the engine.

Disadvantages of LPG as a fuel:-

1) Ignition temperature of LPG is higher than gasoline, so it can lead to the reduction of valve life by 5%.
2) Very good cooling system is required, as LPG vaporizer uses coolant to provide the heat to convert it into vapor from liquid state.
3) Vehicle weight is increased as high pressure cylinders are required to store LPG.
4) A special fuel feed system is required for LPG.

Other possible fuels:-

Nowadays a number of biomass fuels are being tested to be used in ic engine as fuel. This includes fuel oil obtained from wood, barley, rapeseed, soya beans and even beef tallow.

Advantages of these fuels are:-

1) Widely available, that means low cost.
2) Sulphur content is low.
3) Emissions are also very less.

Disadvantage of using these fuels is that they have lower energy content so the specific fuel consumption increases.

The examples of these fuels are biogas, producer gas, blast furnace gas, coke oven gas, benzol, acetone and diethyl ether.

S.No.	FUEL	AUTO-IGNITION TEMPERATURE (K)	DENSITY (kg/m3)	FLAMMABILITY LIMIT (%vol in air)
1	LPG	678-723	2.26	2.15
2	CNG	813	0.79	5
3	HYDROGEN	858	0.08	4
4	BIOGAS	923	1.2	7.5
5	DIESEL	523	840	NA
6	GASOLINE	644	710-750	1.4

Turpentine oil:-

It is obtained by distillation of resin which is obtained from trees generally pine trees. It is combination of α-pinene (65-70)% and β-pinene (30)%. It is mainly used as thinner for paints. It also has a medicinal use.

Properties of turpentine oil:-

1) colourless, characterstic odor and taste.
2) Soluble in 5 vol of alcohol.
3) When perfectly pure, it exclusively consists of carbon and hydrogen.

Physical:-

1) boiling point-(153-175)c.
2) flash point-35c.
3) viscosity-1.257mPas
4) specific gravity-(.850-.865)
5) cp = 1720 (J/kgK)

Solubility:-Insoluble in water, soluble in benzene, chloroform, ether, carbon disulphide, petroleum oils.

Advantages of turpentine oil over diesel:-

1) It is a renewable fuel , which is obtained from pine trees.
2) Self-ignition temperature of turpentine oil is near to that of diesel.
3) Boiling point is also almost same as that of diesel.
4) Calorific value of turpentine oil is higher than that of diesel.
5) It has same viscosity as that of diesel.
6) Compared with other biofuels, turpentine has 11-15% higher calorific value.

Acetylene:-

Pure acetylene is a colorless, highly flammable gas with an ether-like odor, but the odor of the commercial purity grade is garlic-like. Acetylene can be safely stored and used in cylinders filled with a porous material and containing acetone into which the acetylene has been dissolved.

Acetylene, when not dissolved in a solvent can begin to decompose at pressures above 15 pounds per square inch gauge (psig). The products of dissociation are carbon, in the form of lampblack and hydrogen. Considerable amounts of heat are generated by dissociation, which may produce explosions of great violence. Steel and wrought iron are recommended for use in acetylene piping. Rolled, forged, or cast steel, or malleable iron fittings may be used. Cast iron is not permissible for fittings. Unalloyed copper, silver, or mercury should never be used in direct contact with acetylene since there is the possibility of forming explosive acetylides. Wet acetylene will produce explosive acetylides on copper, 70-30 brass, and aluminum-bronze. Weight (not pressure) is used to determine the amount of acetylene in a cylinder. The tare weight is subtracted from the actual weight, and the difference is multiplied by 14.7 to determine the amount of gas in standard cubic feet. The molecular symbol for acetylene is C_2H_2.

Physical and Chemical Properties

APPEARANCE: Colorless gas

ODOR: Acetylene of 100% purity is odorless, but commercial acetylene has a distinctive, garlic-like odor.

PHYSICAL STATE: Gas at normal temperature and pressure

SUBLIMATION POINT at 1 atm**:** -118°F (-83.3°C)

MELTING POINT at 10 psig (170 kPa abs)**:** -116°F (-82.2°C)

BOILING POINT at 10 psig (170 kPa abs)**:** -103.4°F (-75.2°C)

FLASH POINT: -0°F (-17.8°C)

FLAMMABLE LIMITS IN AIR, % by volume**: LOWER:** 2.5% **UPPER:** 100%

VAPOR PRESSURE at 70°F (21.1°C)**:** 649.6 psia (4479 kPa abs)*

VAPOR DENSITY at 32°F (0°C) and 1 atm**:** 0.07314 lb/ft3 (1.1716 kg/m3)

SPECIFIC GRAVITY (Air = 1) at 32°F (0°C) and 1 atm**:** 0.906

SOLUBILITY IN WATER vol/vol at 32°F (0°C)**:** 1.7

AUTOIGNITION TEMPERATURE: 581°F (305°C) at 1 atm

PERCENT VOLATILES BY VOLUME: 100

MOLECULAR WEIGHT: 26.04

MOLECULAR FORMULA: C_2H_2

Comparison of the properties of acetylene and turpentine oil with diesel and gasoline

Table

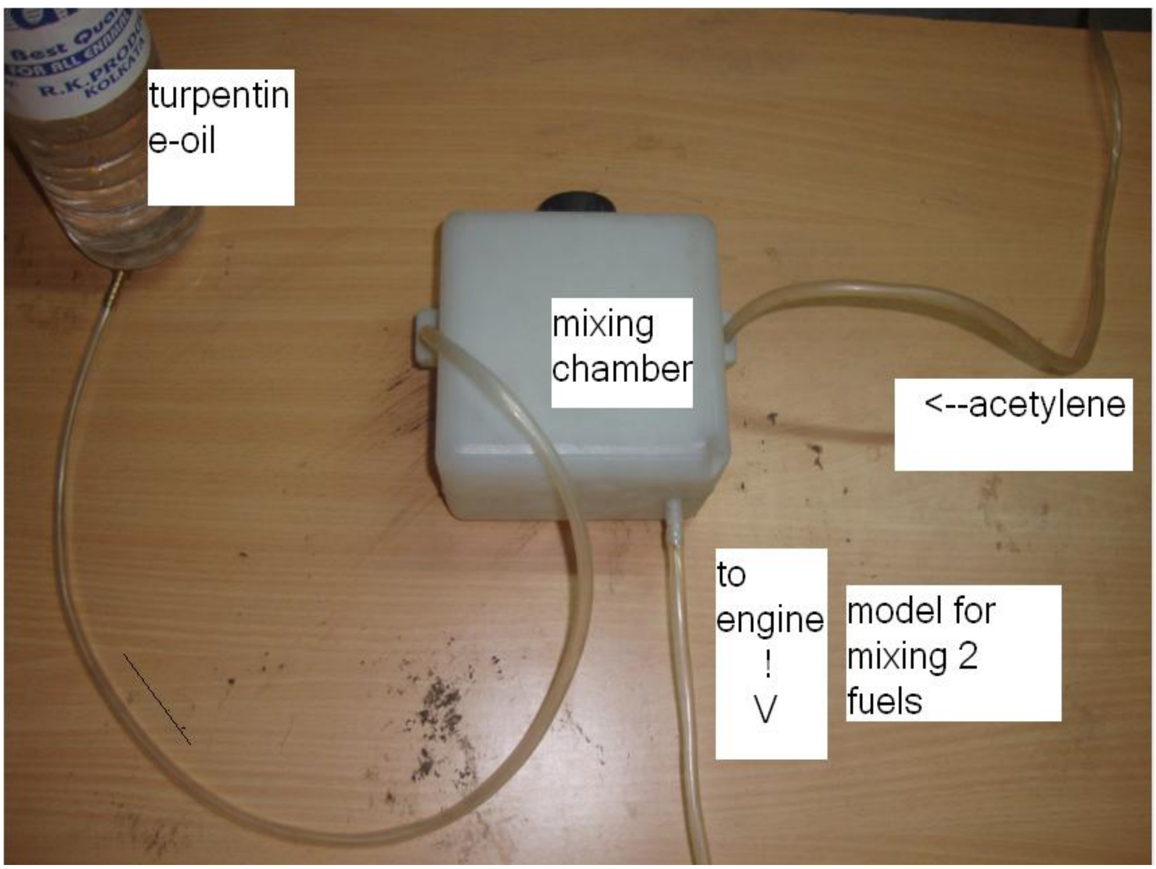
S.No.	**PROPERTY**	**GASOLINE**	**DIESEL**	**ACETYLENE**	**TURPENTINE OIL**
1	FORMULA	C4-C12	C8-C25	C_2H_2	$C_{10}H_{16}$
2	DENSITY (kg/m^3)	780	840	1.092	860-900
3	AUTO-IGNITION TEMPERATURE (^{0}C)	300-400	250	305	305
4	FLAMMABILITY LIMIT (% vol)	1.4	1.0	2.5-81	0.8
5	LOWER HEATING VALUE (kJ/kg)	43,890	42,700	48,225	44,400

Chapter 3

Experimental setup and the

Properties of mixture

Experimental set-up



Properties of the mixture of acetylene and turpentine oil

Properties of acetylene:

P1 = 1.092 (kg/m^3)

CV1 = 48,225 (kJ/kg)

Cp1 = 1674 (J/kgK)

m1 = mass flow rate

T1 = temperature

Properties of turpentine oil:

P2 = 860-900 (kg/m^3)

CV2 = 44,400 (kJ/kg)

Cp2 = 1720 (J/kgK)

m2 = mass flow rate

T2 = temperature

Properties of mixture:

$$T = \frac{m1 * cp1 * T1 + m2 * cp2 * T2}{m1 * cp1 + m2 * cp2}$$

$$CV = \frac{m1 * CV1 + m2 * CV2}{m1 + m2}$$

$$\rho = \frac{m1 * \rho1 + m2 * \rho2}{m1 + m2}$$

Chapter 4

Methodology

Engine performance parameters:-

1) indicated thermal efficiency
2) brake thermal efficiency
3) mechanical efficiency
4) volumetric efficiency
5) relative efficiency
6) mean effective pressure
7) mean piston speed
8) specific power output
9) specific fuel consumption
10) calorific value of the fuel

Indicated thermal efficiency $(\boldsymbol{\eta ith})$ is the ratio of energy in the indicated power to that of the energy provided by the fuel. Indicated power is the power provided by the combustion of fuel to the piston.

$$\eta ith = \frac{ip(\frac{kJ}{s})}{energy\ in\ fuel\ per\ second(\frac{kJ}{s})}$$

$$\eta ith = \frac{ip}{mass\ flow\ rate\ of\ fuel * calorific\ value\ of\ fuel}$$

Brake thermal efficiency ($\boldsymbol{\eta bth}$) is the ratio of energy in the brake power to that of the energy provided by the fuel. Brake power is the power delivered by the engine.

$$\eta bth = \frac{bp}{mass\ flow\ rate\ of\ fuel * calorific\ value\ of\ fuel}$$

Mechanical efficiency($\boldsymbol{\eta mech}$**)** is defined as the ratio of the power delivered i.e. brake power to the power available at the piston i.e. indicated power.

$$\eta mech. = \frac{bp}{ip}$$

Volumetric efficiency ($\boldsymbol{\eta v}$) gives the breathing capacity of engine. Volumetric efficiency is defined as the rate of air inducted in the engine to the volume displaced by the piston.

$$\eta v = \frac{ma}{\rho a * Vd}$$

Where,

m_a = mass flow rate of air in the intake system

ρa = density of air

V_d = volume displaced by the piston

In calculating volumetric efficiency, air flow rate is taken into account, not the mixture flow rate. So, the volumetric efficiency of diesel engine is greater than SI engine as charge is inducted in SI engine. Normally for SI engines, volumetric efficiency varies from 80-85% and for CI engine the value is 85-90%.

Relative efficiency (ηrel) is the ratio of thermal efficiency of actual cycle to that of an ideal cycle. It is a useful criterion for design of an engine. The value should be less than 1.

$$\eta rel = \frac{actual\ thermal\ efficiency}{air - standard\ efficiency}$$

Mean effective pressure (Pm) is defined as the average pressure inside the cylinder of an IC engine based on the power output of the engine. It is given by the following equation.

Indicated mean effective pressure:-

$$Pim = \frac{6000 * ip}{L * A * n * K}$$

Where,

Ip = indicated power (kW)

L = stroke length (m)

A = piston area (m2)

n = number of power strokes

K = number of cylinders

Brake mean effective pressure:-

$$Pim = \frac{6000 * bp}{L * A * n * K}$$

All the other parameters are same except bp i.e. brake power.

Other definition of mean effective pressure can be given from P-V diagram as

$$Pm = \frac{area\ of\ the\ indicator\ diagram}{length\ of\ the\ indicator\ diagram}$$

Mean piston speed (sp) it is defined by the equation:-

sp = 2*L*N

Where, N is the rotational speed of the crankshaft in rpm. It ranges from 8-15 m/s. automobiles operate at the higher range and large marine diesel engines operate at the lower end of the range.

Specific power output (Ps) is the power output of the engine per unit piston area. It is used as a design criterion as the engineers design an engine of given piston area to have a specified power.

Ps = bp/A

= constant*Pbm*sp

Specific fuel consumption (sfc) is the consumption of fuel in kilograms of fuel to give one kilowatt-hour of energy. It reflects the performance of the engine. Lower the value of sfc, better will be the engine.

$$sfc = \frac{fuel\ consumption\ per\ unit\ time}{power}$$

Calorific value (CV) is the thermal energy releases per unit quantity of fuel when the fuel is burned completely and the product of combustion are brought back to the initial temperature of the fuel air mixture. It is also called heat value or heat of combustion. Lower calorific value is the heat released when the water vapors are not condensed and remain as a vapor form only. And the heat released when the products are cooled to 25^{o}c i.e. water vapors are condensed is called higher calorific value.

Chapter 5

Calculations

Calculations:-

Our aim is to get an optimized mixture of the two fuels i.e. acetylene and turpentine oil which leads to a brake thermal efficiency of about 30% at different loads viz. 30%, 50%, 75% and full load (i.e. 100%).

Brake thermal efficiency is given by

$$\eta bth = \frac{bp}{mass\ flow\ rate\ of\ fuel * calorific\ value\ of\ fuel}$$

Also, calorific value of the mixture is given by

$$CV = \frac{m1 * CV1 + m2 * CV2}{m1 + m2}$$

Where,

m1 = mass flow rate of acetylene (kg/h)

m2 = mass flow rate of turpentine oil (kg/h)

CV1 = calorific value of acetylene = 48,225 (kJ/kg)

CV2 = calorific value of turpentine oil = 44,400 (kJ/kg)

CV = calorific value of the mixture (kJ/kg)

Now, mass flow of the fuel into the engine = m1+m2

So, mass flow * calorific value = $m1 * CV1 + m2 * CV2$ (kJ/h)

But in the above equation for the brake thermal efficiency the numerator is in (kJ/s) and denominator in (kJ/h) to make the denominator in (kJ/s), denominator is divided by a factor of 3600 or the numerator is multiplied by 3600. The resulting equation becomes after substituting the value of the denominator and after making both numerator and denominator in same units.

$$\eta bth = \frac{bp * 3600}{m1 * CV1 + m2 * CV2}$$

To get an optimized mixture i.e. (ηbth = 30%), we fix the flow rate of acetylene. And at different engine loads, we have bp (7.5bhp = 5.6kW) of the engine. Calorific value of both the fuels is known. So in the above equation, all the values except mass flow rate of turpentine oil is known. Putting all the values for an efficiency of 30%, we can get the mass flow rate of turpentine oil. Hence the fraction of the two fuels in the optimized mixture is known.

Let the mass flow rate of turpentine oil be x (kg/h), then the above equation can be written as

$$\eta bth = \frac{bp * 3600}{m1 * CV1 + x * CV2}$$

And x can be calculated from the above equation.

Now doing the analysis, three flow rates (0.20kg/h, 0.30kg/h, 0.40kg/h) are selected for acetylene, and for each flow rate, the calculation is done for different engine loads (30%, 50%, 75% and 100%) to get the corresponding flow rate of the turpentine oil.

A) m1 = 0.20 (kg/h)

a) <u>30% load</u>

$$0.3 = \frac{5.6 * 0.3 * 3600}{0.20 * 48225 + x * 44400}$$

$$0.06 * 48225 + 0.3 * x * 44400 = 6048$$

$$13320 * x + 2893.5 = 6048$$

$$13320x = 3154.5$$

$$x = 0.236\ kg/h$$

b) <u>50% load</u>

$$13320x + 2893.5 = 5.6 * 0.5 * 3600$$

$$13320x = 10080 - 2893.5$$

$$13320x = 7186.5$$

$$x = 0.539\ kg/h$$

c) <u>75% load</u>

$$13320x + 2893.5 = 5.6 * 0.75 * 3600$$

$$13320x = 15120 - 2893.5$$

$$13320x = 12226.5$$

$$x = 0.917\ kg/h$$

d) <u>100% load</u>

$$13320x + 2893.5 = 5.6 * 3600$$

$$13320x = 20160 - 2893.5$$

$$13320x = 17266.5$$

$$x = 1.29\ kg/h$$

Similarly, the calculations are done for 0.30 kg/h and 0.40 kg/h and the results are obtained for the following cases.

B) m1 = 0.30 (kg/h) and varying the loads
C) m1 = 0.40 (kg/h) and varying the loads

Chapter 6

Results and discussion

The results are shown in tabular form:-

Table A

LOAD (% age)	**m1 (kg/h)**	**m2 (kg/h)**	**ENERGY Acetylene (kW)**	**ENERGY Turpentine-oil (kW)**
30	0.20	0.236	2.679	2.91
50	0.20	0.539	2.679	6.65
75	0.20	0.917	2.679	11.31
100	0.20	1.29	2.679	15.91

Table B

LOAD (% age)	**m1 (kg/h)**	**m2 (kg/h)**	**ENERGY Acetylene (kW)**	**ENERGY Turpentine-oil (kW)**
30	0.30	0.12	4.018	1.48
50	0.30	0.43	4.018	5.30
75	0.30	0.809	4.018	9.97
100	0.30	1.187	4.018	14.64

Table C

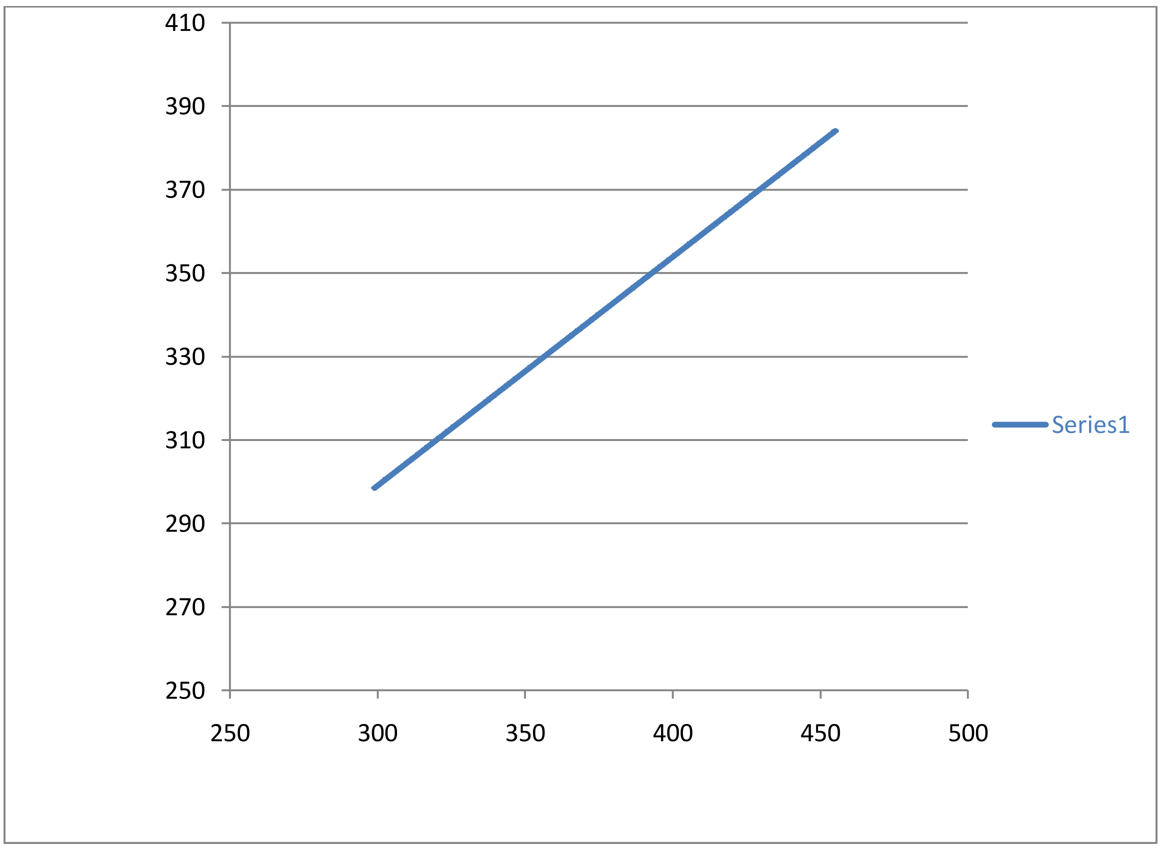
LOAD (% age)	**m1 (kg/h)**	**m2 (kg/h)**	**ENERGY Acetylene (kW)**	**ENERGY Turpentine-oil (kW)**
30	0.40	0.019	5.358	0.234
50	0.40	0.322	5.358	3.97
75	0.40	0.70	5.358	8.63
100	0.40	1.079	5.358	13.31

Properties of the mixture at different conditions are plotted with the above data with the help of a c++ program, data is generated by varying the properties of the two fuels i.e. turpentine oil and acetylene.

Graph1 (mixture temperature v/s turpentine temperature)

y-axis = temperature of the mixture in K

x-axis = temperature of turpentine oil in K

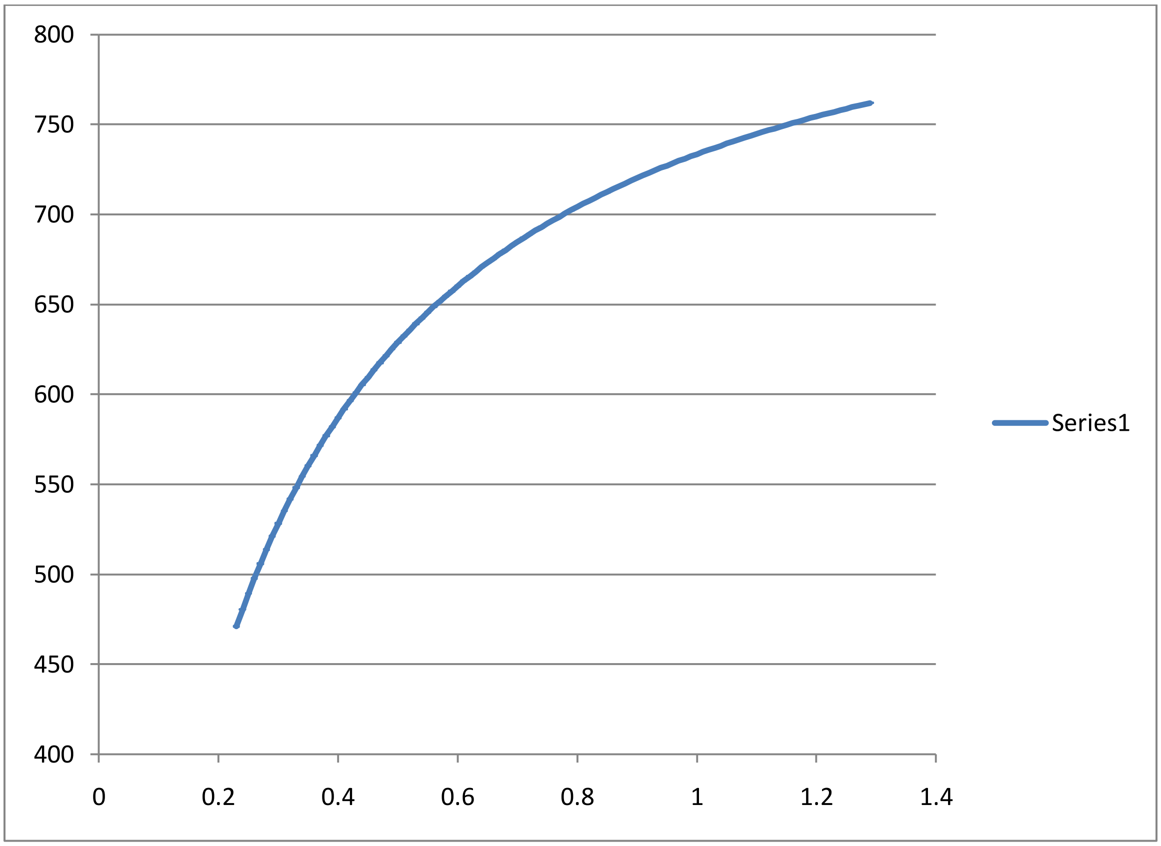


This graph shows the variation of the mixture temperature by varying the temperature of turpentine oil from normal conditions i.e. 298K to the boiling point of the turpentine oil, i.e. when both the fuels are mixed in gaseous form. The value of mass flow rate is fixed here for both acetylene and turpentine oil. So, this graph shows variation of temperature with the change in temperature of turpentine oil only.

In all the following graphs x-axis represents mass flow rate of turpentine oil in kg/h

Graph 2 (density v/s mass flow)

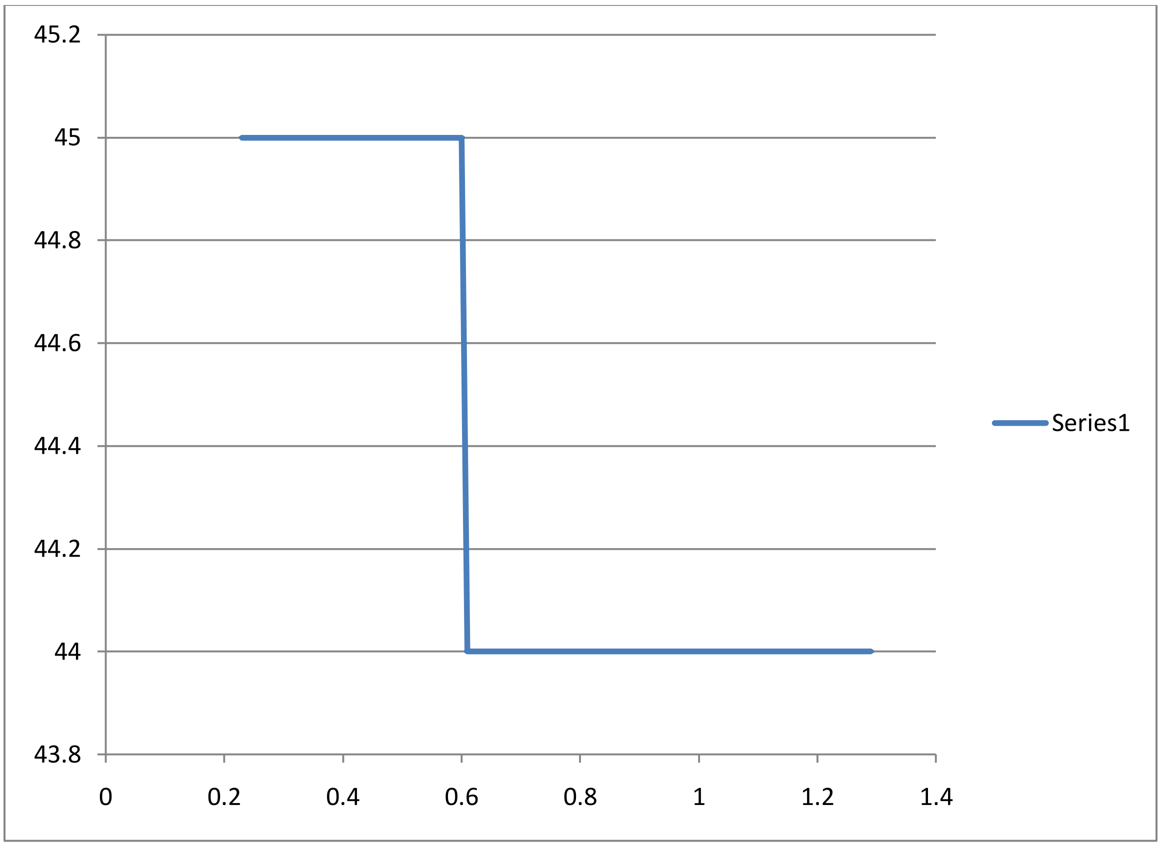
y- axis = density in kg/m^3



In this graph, the mass flow rate of acetylene is fixed to 0.20 kg/h and the mass flow rate of turpentine oil is varied from the mass flow at 30% load i.e. 0.236 kg/h to mass flow at full load i.e. 1.29 kg/h. the values are read from the table of the flow rates (table A) drawn before. As density of turpentine is much greater than that of acetylene, with the increase in mass flow rate of turpentine oil, the density of the mixture increases as shown by the graph.

Graph 3 (calorific value v/s mass flow)

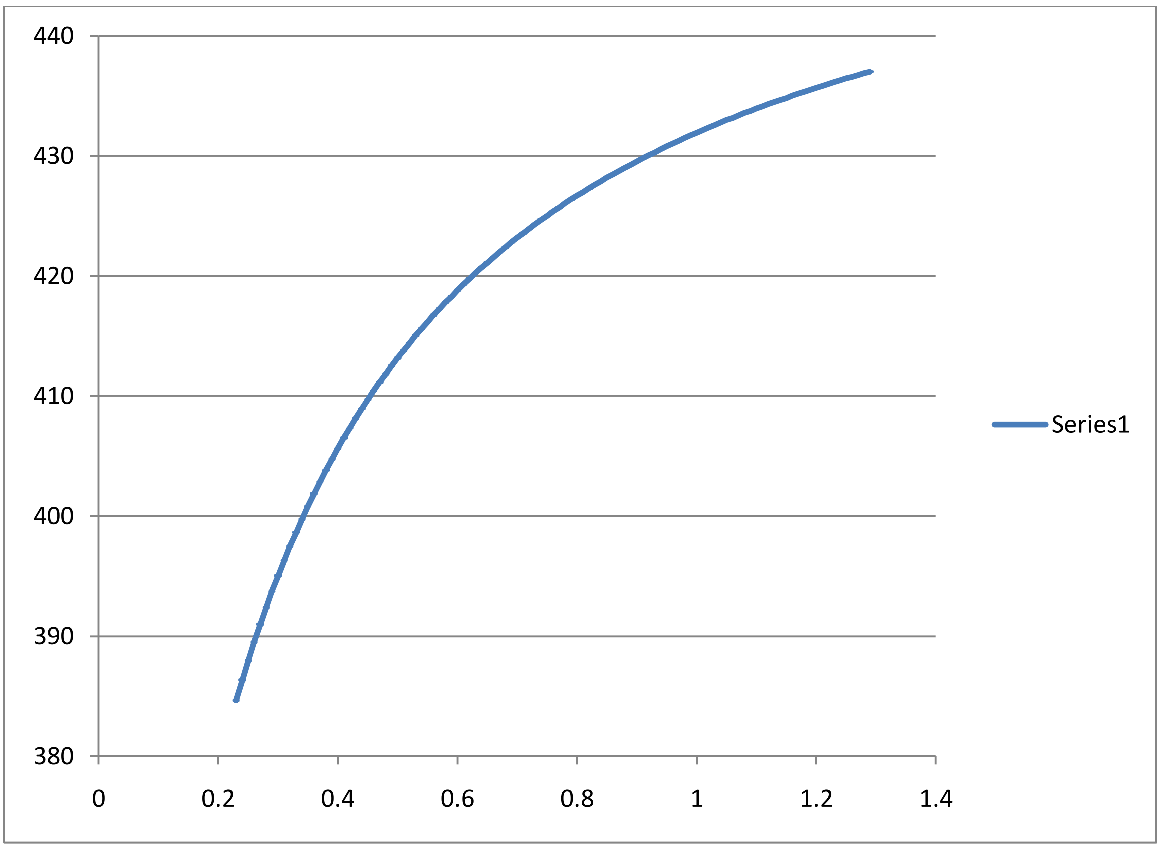
y-axis = calorific value in MJ/kg



For the same flow rate of acetylene, i.e. 0.20 kg/h and varying the flow rates of the turpentine oil as per the table A, we get this graph for the calorific value of the mixture of acetylene and turpentine oil. As it can be seen when the mass flow rate of turpentine oil increases, the calorific value of the mixture decreases, as acetylene has a higher calorific value than that of turpentine oil.

Graph 4 (temperature v/s mass flow)

y-axis = temperature in K



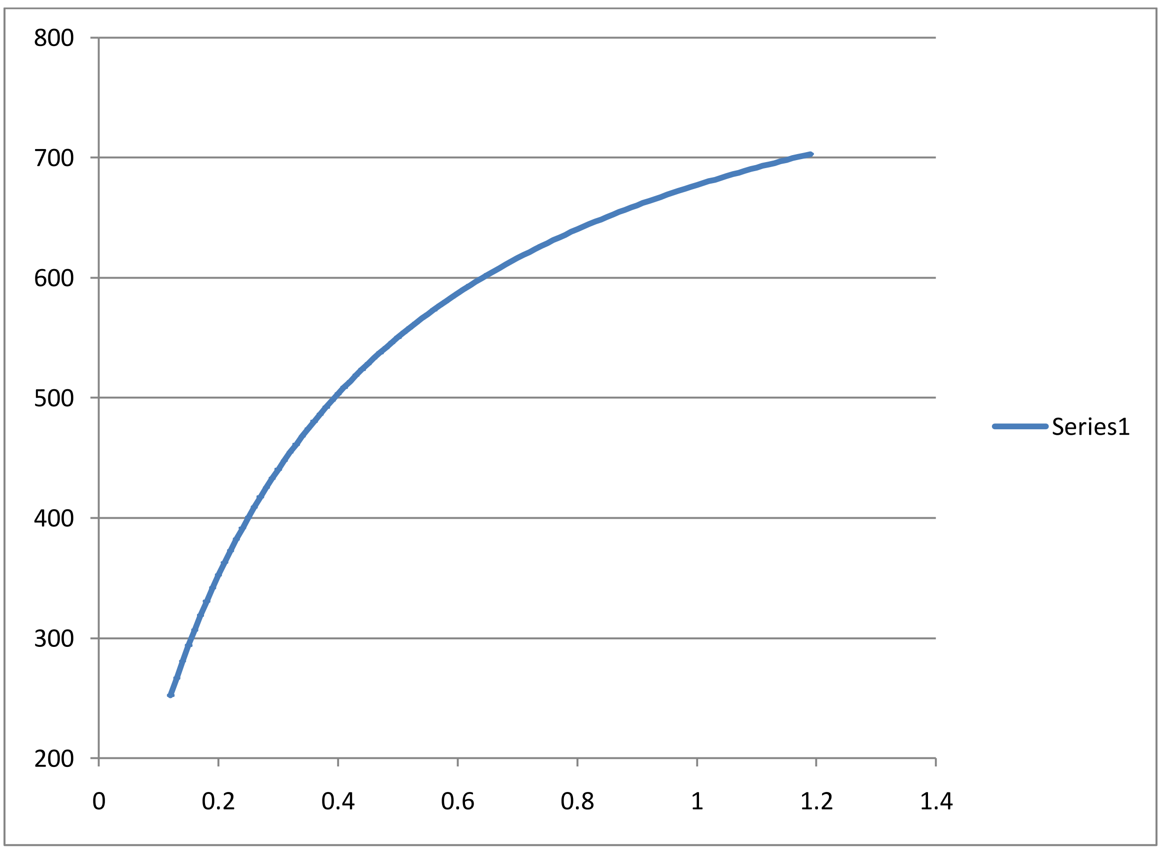
In this graph, again the flow rate of acetylene is taken as 0.20 kg/h. the temperature of acetylene is taken as 298K and that of turpentine oil is taken as 458K i.e. they are mixed in gaseous form. The flow rate of turpentine oil is varied and the temperature of the mixture is obtained. This information can be used in selecting the pipes to be used in the experimental set-up to mix the two fuels.

In the similar manner graphs are plotted by taking the mass flow rate of acetylene as 0.30 kg/h and 0.40 kg/h.

First taking the mass flow rate to be 0.30 kg/h

Graph 5 (density v/s mass flow)

y-axis = density in kg/m^3

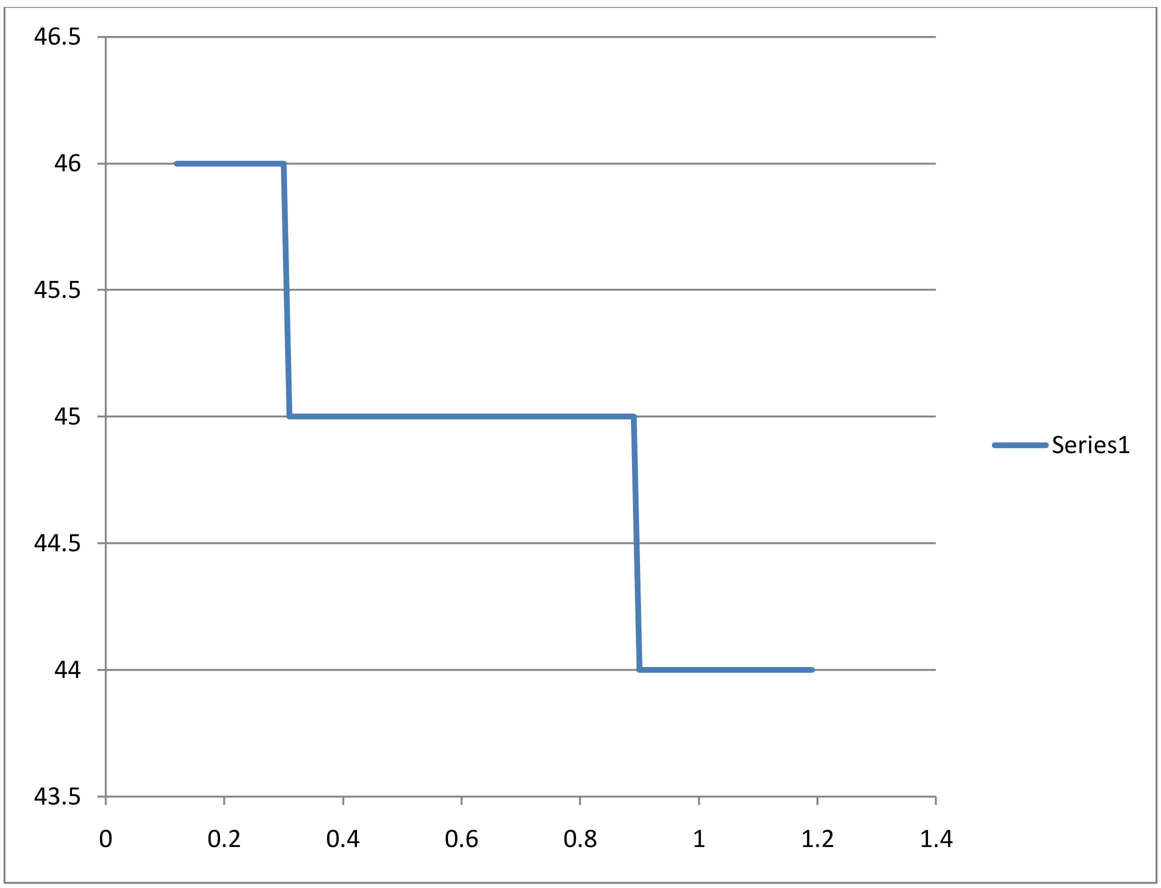


Mass flow rate of acetylene = 0.30 kg/h

Mass flow rate of turpentine oil = 0.12-1.187 kg/h

Graph 6 (calorific value v/s mass flow)

y-axis = calorific value in MJ/kg

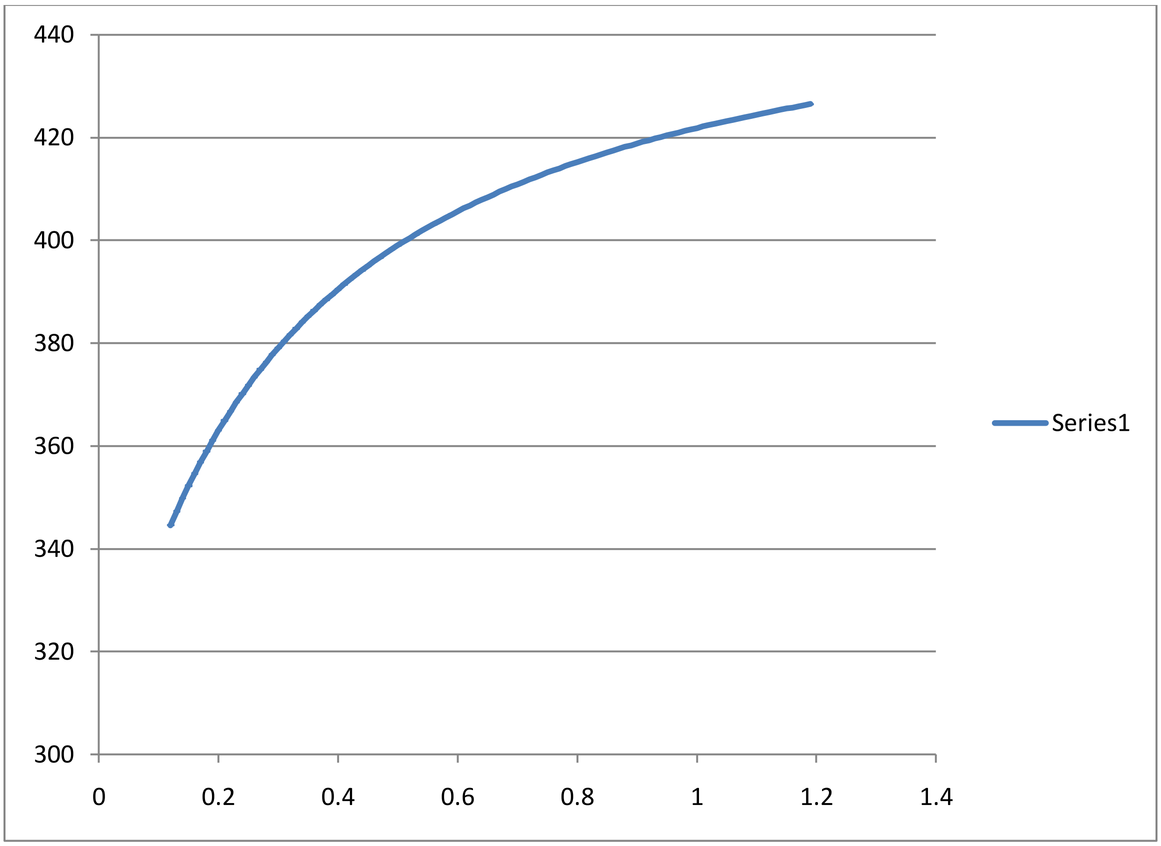


Mass flow rate of acetylene = 0.30 kg/h

Mass flow rate of turpentine oil = 0.12-1.187 kg/h

Graph 7 (temperature v/s mass flow)

y-axis = temperature in K



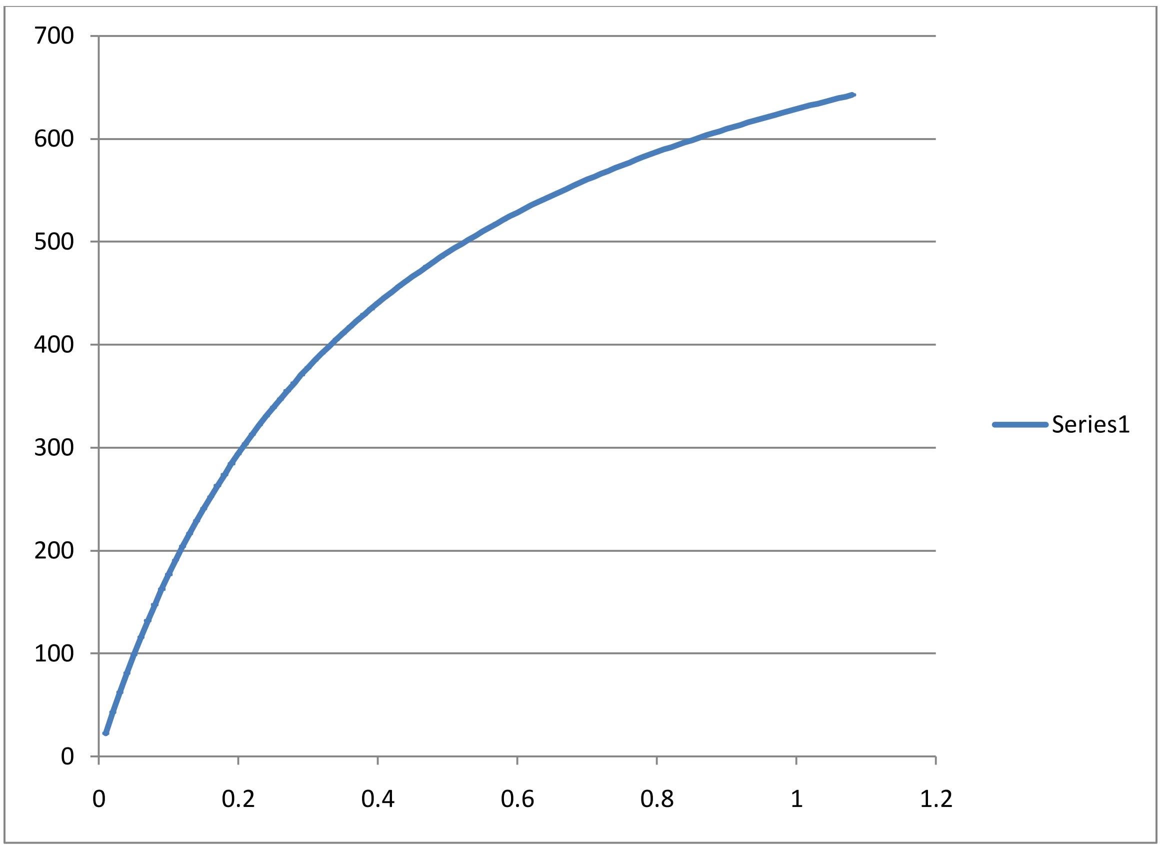
Mass flow rate of acetylene = 0.30 kg/h

Mass flow rate of turpentine oil = 0.12-1.187 kg/h

Now varying the mass flow of acetylene to 0.40 kg/h

Graph 8 (density v/s mass flow)

y-axis = density in kg/m^3

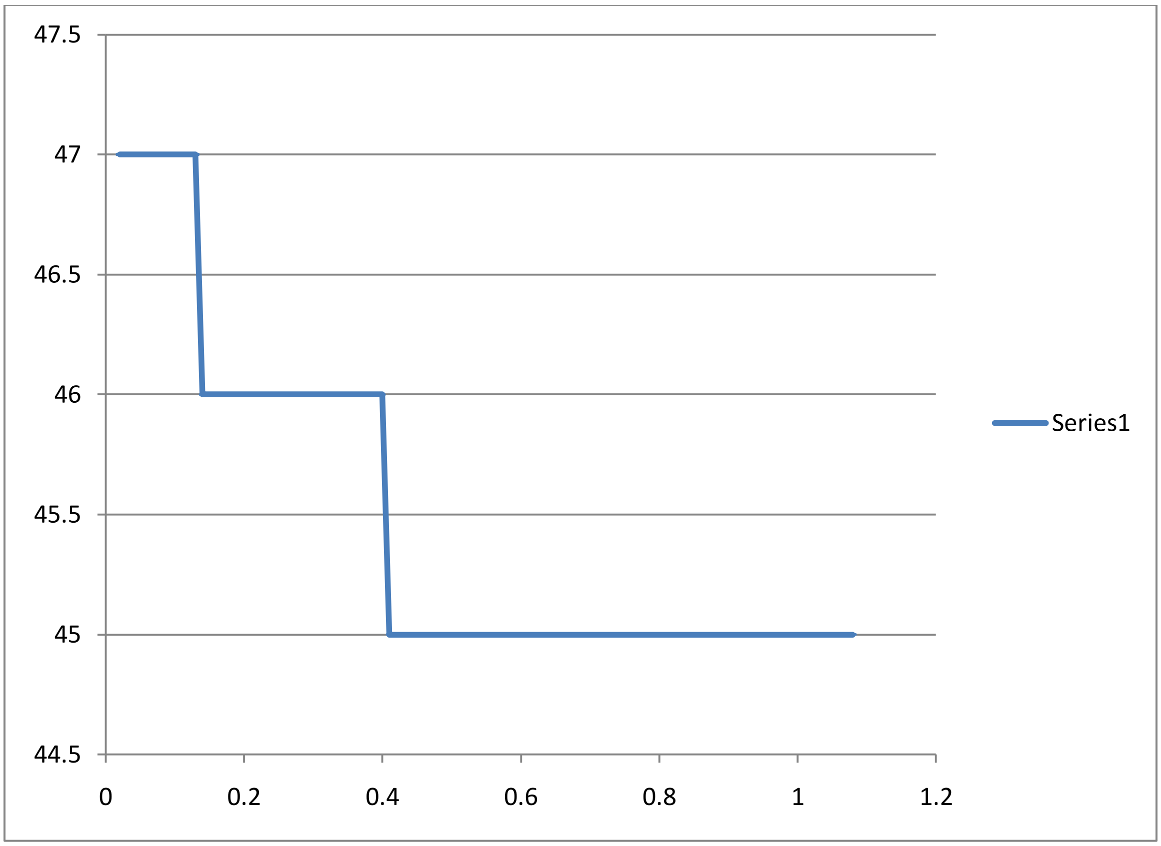


Mass flow rate of acetylene = 0.40 kg/h

Mass flow rate of turpentine oil = 0.019-1.079 kg/h

Graph 9 (calorific value v/s mass flow)

y-axis = calorific value in MJ/kg

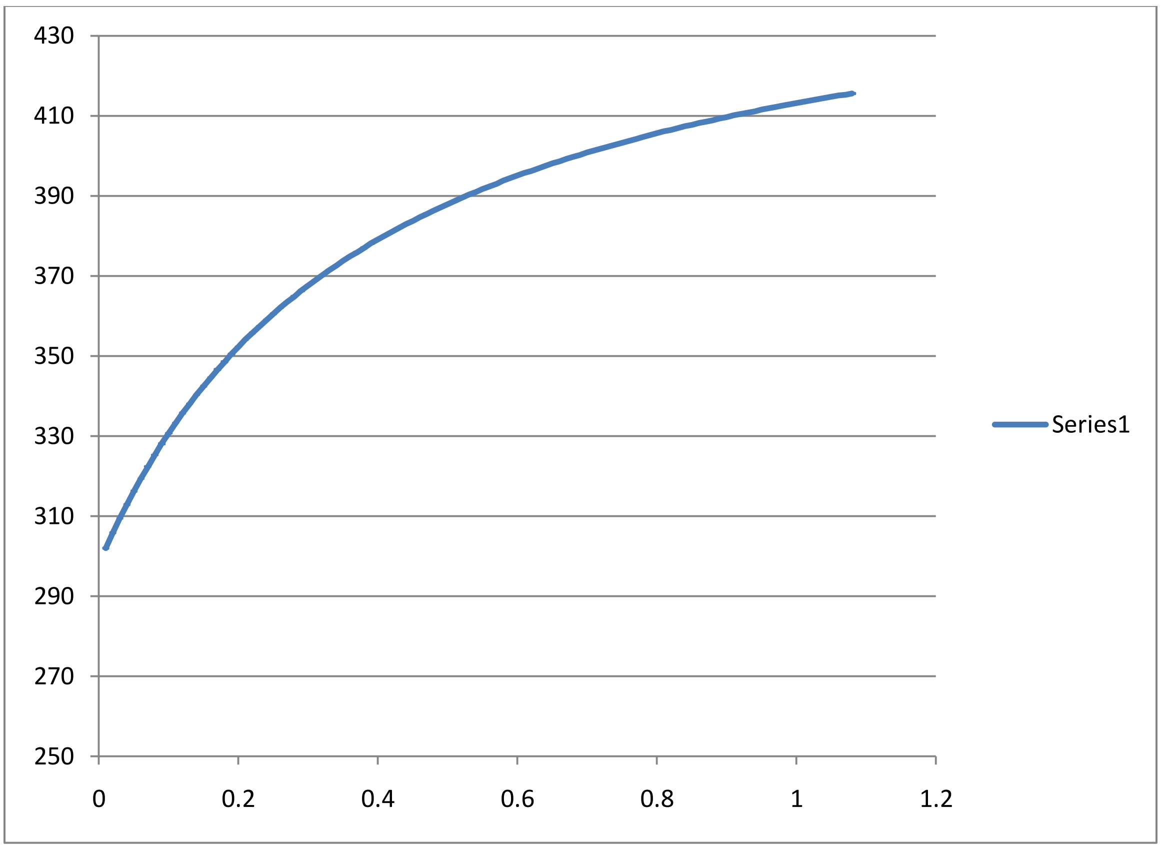


Mass flow of acetylene = 0.40 kg/h

Mass flow rate of turpentine oil = 0.019-1.079 kg/h

Graph 10 (temperature v/s mass flow)

y-axis = temperature in K



Mass flow rate of acetylene = 0.40 kg/h

Mass flow rate of turpentine oil = 0.019-1.079 kg/h

Chapter 7

Conclusion

CONCLUSION

It has already been found out that acetylene and turpentine oil can be used as alternative fuels in direct injection CI engine. So, we have tried to make a mixture of acetylene oil and turpentine oil to be used in direct injection CI engine which can give a thermal efficiency of 30% which is quite good a value. The calculations are done to have thermal efficiency of 30% at different loaded conditions viz. 30%, 50%, 75% and 100% i.e. full load conditions. So, the optimization of the mixture is done to achieve the same. Moreover the properties of the resulting mixture are found out by varying the properties of individual components in accordance of the results obtained. And the properties are expressed in a graphical manner. Seeing these properties an apparatus can be designed on a large scale for mixing acetylene and turpentine oil to be used in a direct injection CI engine.

Chapter 8

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